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Original Article

Initial Compartment 1 pH Response to Grain Supplementation in Alpacas (*Vicugna pacos*) Fed Alfalfa and Grass Hay

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Abstract

The purpose of this study was to determine the diurnal pH variation of the first compartment stomach (C1) of alpacas (vicugna pacos) fed grass hay (GH) or alfalfa hay (AH) and initial addition of grain supplements; oats (O), corn (C) or corn/oats/barley (COB) and to determine the effects of initial inclusion of corn to GH at levels of 0, 35, 50 and 70% of dry matter intake on C1 pH. Two experiments were conducted with four male (+3 yrs, 65 kg BW) alpaca fitted with C1 fistula. Alpaca were housed in metabolism crates and fed ad libitum hay and water. Experiment 1 treatments (TRT) included supplementation of 454 g of oats (O), ground corn (C), corn/oats/barley/molasses (COB) to AH (AO, AC, ACOB) and GH (GO, GC, GCOB). Two alpacas were acclimated to AH and the other two to GH. Each grain TRT was randomly administered followed by a 30 d acclimation period to the other forage and random administration of each grain. A pH probe was fitted through the fistula and positioned at the anterior, ventral portion of C1. Treatment periods included d1 to d7 diurnal pH collection of AH or GH, d8-10, d15-17 and d22-24 for grain TRT. Dry matter intake (DMI) was 1415, 1146, 1142 and 1192g for AH, AC, AO and ACOB; and 1331, 1206, 1207, and 1260 for GH, GC, GO and GCOB. AH was different from AH+grain TRT ($P<0.05$). Overall pH was 6.87, 6.78, 6.78 and 6.56 for AH, AC, AO and ACOB; and 6.95, 6.76, 6.89 and 6.83 for GH, GC, GO and GCOB ($P<0.05$). TRT and Time were significant ($P<0.05$). For EXP 2 GH was supplemented with 0 (G0C), 454g (G1C), 731g (G2C) and 908g (G3C) of corn. DMI was not affected. Overall pH decreased from 7.27 to 7.08 for G0C to G3C ($P<0.05$). Diurnal pH was significant for TRT ($P<0.05$), but not Time. Initial or abrupt feeding of grains to alpacas does elicit a pH response, but not to the extent of other true ruminants. This may be attributed to the buffering capacity of the C1, but further research is needed.

Keywords: Alpaca, pH, compartment 1, diurnal, corn, oats, barley, alfalfa, grass.

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Introduction

South American camelids have a unique digestive physiology that has not been extensively researched. Classified as pseudoruminants, camelids have three stomach compartments instead of four found in true ruminants. Camelids have mucosal tissue called glandular saccules associated with compartment 1 (C1) and C2 that excrete bicarbonate (Eckerlin and Stevens, 1973; Rübsamen and Engelhardt, 1978). This gives the camelid the ability to maintain an optimal pH environment where C1 microbes can flourish. AlZahal et al., (2007) demonstrated the use of a continuous pH method in cattle and the diurnal pattern when fed alfalfa hay. They showed that over a 24-hr period the pH decreased post-feeding until 12-hrs at which the pH increased back to the feeding point. Similar patterns were also found in sheep (Aguerre et al., 2009)

Several grains are used as supplements to grass hay diets by alpaca producers. To our knowledge the effect of the abrupt addition of grain on C1 pH has not been determined and is important in understanding the dynamics of digestion in alpacas. Most producers are extrapolating sheep and goat digestion parameters to alpacas; which we are finding, though close, are not accurate.

The purpose of this study was to determine the diurnal pH variation within the first stomach, compartment 1 (C1), of alpacas (*vicugna pacos*) fed grass hay (GH) or alfalfa hay (AH) and initial addition of differing grain supplements including oats, ground corn or corn/oats/barley/molasses. We also wanted to determine the effects of initial inclusion of ground corn at various levels on C1 pH.

Material and methods

Animals and Instrumentation

Four adult male alpacas (3+ years old; 66kg) were housed in metabolic crates for two weeks prior to the beginning of this experiment. Each alpaca was fed ad libitum either a grass (tall fescue, *Festuca arundinacea*) or alfalfa (*Medicago sativa*) hay for experiment 1 (EXP 1) and a mixed grass hay consisting of meadow brome (*Bromus biebersteinii*), orchard (*Dactylis glomerata*), timothy (*Phleum pretense*), and tall fescue for experiment 2 (EXP 2). Each alpaca was provided with ad libitum water. Compartment 1 fistula (Model 4C, Bar Diamond, Parma, ID, USA) were placed into the alpacas prior to this experiment and all husbandry followed animal use and care guidelines.

A pH probe (PHE-7352-15-PT100, Omega Engeneering, CT, USA) was fitted through an extra fistula stopper and connected to a wireless transmitter (UWPH-2-NEMA, Omega Engeneering, CT, USA). Data was collected real-time by a receiver (UWTC-REC1, Omega Engeneering, CT, USA) connected to a computer at 5 min intervals. The pH probe was inserted the day prior to the beginning of each sampling period.

Treatments

This study was composed of two experiments where experiment 1 (EXP 1) treatments (TRT) included the addition of 454 g of oats (O), ground corn (C), corn/oats/barley/molasses (COB) to GH (GO, GC, GCOB) or to AH (AO, AC, ACOB). The alpacas were divided into two groups of two and adjusted to AH or GH for 30-d. Each grain TRT was randomly administered to each alpaca. Once the grain TRT had been administered the alpacas were switched to the other forage followed by a 30-d acclimation period. The grains TRT were again randomly administered to each alpaca.

The pH probe was calibrated and positioned at the anterior, ventral portion of C1 one day prior to beginning of data collection. Treatment periods included d1 to d7 diurnal pH collection of AH or GH. Grain TRT pH data was collected during d8-10, d15-17 and d22-24 real-time at 5 minute intervals. Diurnal patterns for a 24-hour period are the average of the 3-d collection period. The TRT grain was provided first and was consumed within 15 minutes followed by the feeding of the forage.

For experiment 2 (EXP 2) the alpacas were fed GH and in addition received each of four corn TRT in random order; GH (G0C), GH+454 g C (G1C), GH+908 g C (G2C) and GH+1362 g C (G3C). During d1-3, d8-11, d15-18 and d22-d25 the TRT was administered and pH data collected real-time at 5 minute intervals.

Statistical Analysis

Experiment 1: The pH data were analyzed using a linear mixed model with forage/grain, time, and forage/grain by time interaction as main effects with time treated as a repeated measure (Littell et al.,, 1998). Replicates, alpacas within replicates, and the replicate by forage interaction were specified as random effects. The SAS (SAS, Inst., Cary, NC) procedure MIXED was used for all calculations and a probability of P<0.05 was considered significantly different. Least squares means for levels of the forage/grain and time factors were calculated and compared using unadjusted *t* tests.

Experiment 2: The data were analyzed using mixed model with TRT, Time and the interaction as the main effects. Time was treated as a repeated measure. Replicates, alpacas within replicates, and the replicate by TRT interaction were specified as random effects. These data were run through the SAS PROC MIXED as above with the least square means for TRT, Time and the interaction calculated and compared using unadjusted *t* tests.

Results

Experiment 1

Composition of the forages and grains are presented in Table 1. Dry matter intake (see Table 3) was not different between GH and AH. The addition of grain to AH did result in reduced DMI (P<0.05) from 1415 g/d to 1142, 1146 and 1192 for AH, AO, AC and ACOB, respectively.

The mean pH over the 24-hr period (see Table 3) was 6.87, 6.78, 6.78 and 6.56 for AH, AO, AC and ACOB; and 6.95, 6.89, 6.76 and 6.83 for GH, GO, GC and GCOB. Alfalfa pH was more acidic than GH ($P < 0.05$) and was more basic than AO and AC which are more basic than ACOB ($P < 0.05$). All GH TRT were different from each other ($P<0.05$).

Table 1: Chemical composition of feeds fed in experiment 1[a].

	Alfalfa Hay	Grass Hay	Corn	Oats	COB[b]
DM, %	91.1	90.8	88.0	91.1	89.8
Crude protein, %	18.2	17.0	9.0	10.6	10.5
NDF, %	49.7	59.7	9.4	30.2	21.3
ADF, %	35.9	34.0	3.2	15.7	8.1
Fat, %	2.0	3.4	4.5	6.4	ND
Ash, %	8.7	10.0	1.6	3.2	ND

[a]Composition expressed on dry matter (DM) basis.
[b]COB = corn/oats/barley/molasses; ND = not determined.

Table 2: Chemical composition of feeds fed in experiment 2[a].

	Grass Hay	Corn
DM, %	93.7	89.0
Crude Protein, %	7.6	9.8
NDF, %	54.8	11.6
ADF, %	37.0	4.2
Fat, %	2.8	4.5
Ash, %	9.5	1.9

[a]Composition expressed on dry matter (DM) basis.

Diurnal pH patterns for each TRT (see Fig 1) showed a decrease in pH followed by a return. As indicated by overall pH, the COB pattern decreased the lowest (P<0.05) for both GH and AH before returning. The TRT and Time effects were significant (P<0.05), but the interaction was not significant.

Experiment 2

Composition of the grass forage and corn used for this experiment is presented in Table 2. Dry matter intake (see Table 4) was not affected by the increase of corn in the diet.

Table 3: Effects of initial feeding of alfalfa and grass hay with corn, oats or COB (corn/oats/barley/molasses) on intake and 24-hr mean compartment 1 pH (Experiment 1).

	Alfalfa Hay				Grass Hay				SEM
	Alfalfa	Corn	Oats	COB	Grass	Corn	Oats	COB	
DM intake, g/d	1415[a]	1146[b]	1142[b]	1192[b]	1331[ab]	1206[ab]	1207[ab]	1260[ab]	83.7
24-hr mean pH	6.87[a]	6.78[b]	6.78[b]	6.56[c]	6.95[d]	6.76[b]	6.89[a]	6.83[ab]	0.03

[abcde]Values within row with differing superscripts are significantly different at P<0.05.

Table 4: Effects of initial feeding of grass hay with varying levels of corn on intake and 24-hr mean compartment 1 pH (Experiment 2).

	Corn[a]				SEM
	G0C	G1C	G2C	G3C	
DM intake, g/d	1122	1215	1334	1225	56.4
24-hr mean pH	7.27[b]	7.20[c]	7.11[d]	7.08[e]	0.006

[a]G0C = grass hay + 0g corn; G1C = grass hay + 454g corn; G2C = grass hay + 731g corn; G3C = grass hay + 908g corn.
[bcde]Values within row with differing superscripts are significantly different at P<0.05.

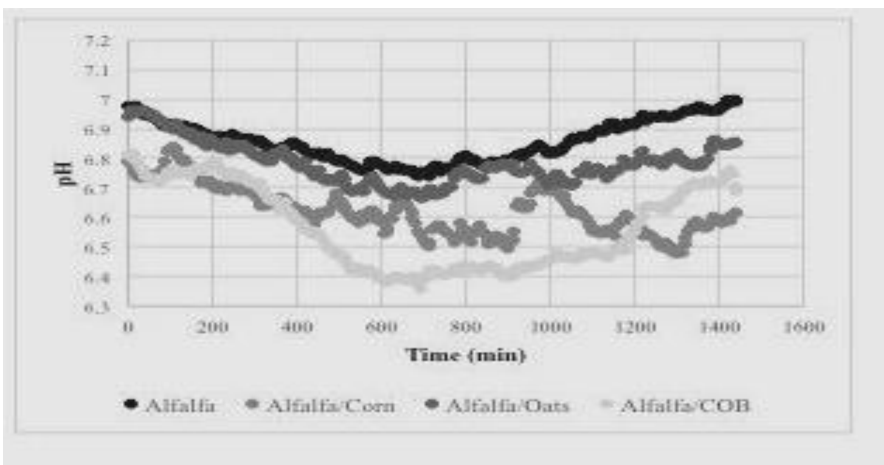
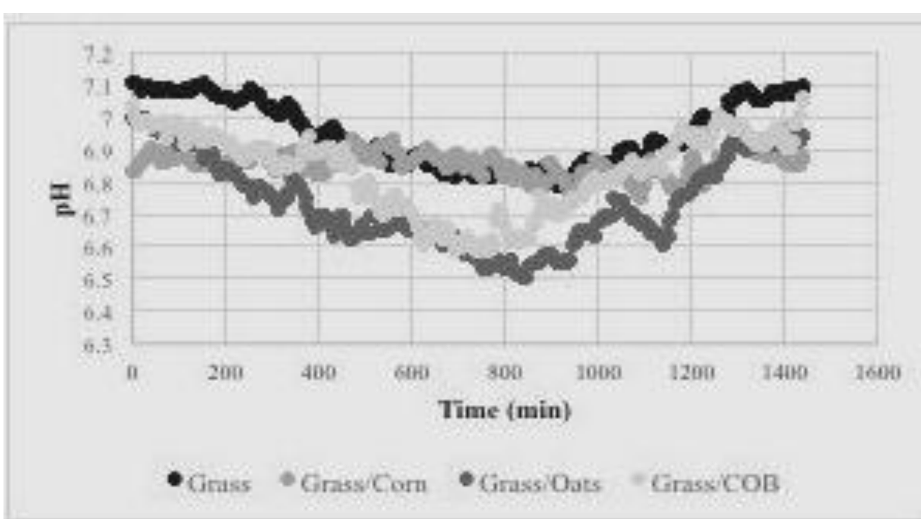


Fig. 1. Effect of initial feeding of corn, oats or corn/oats/barley/molasses (COB) on compartment 1 pH of alpacas fed alfalfa or grass hay. TRT and Time were significant (P<0.05), while the interaction was not.



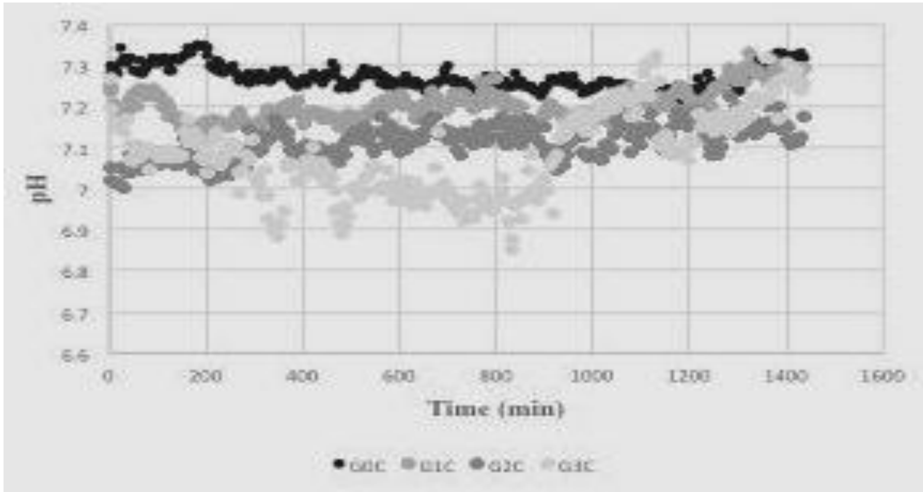


Fig. 2. Effect of initial feeding of varying levels of corn (C) on compartment 1 pH of alpacas fed grass hay. G0C = grass hay + 0G corn, G1C = grass hay + 454g corn, G2C = grass hay + 731g corn and G3C = grass hay + 908g corn. Time and TRTxTime interaction were not significant; TRT was significant at P<0.05.

Our target for corn inclusion was 0, 35, 50 and 70% of DM intake. Intake levels being what they were, these became 0, 37, 55 and 74% of DM intake. Overall pH mean between the four TRT were different from each other at P<0.05. Time and the TRT x Time interaction were not significantly different. The diurnal pH patterns for the four TRT are shown in Fig 2. Corn inclusion level was significant (P<0.05) and the same pattern of decreasing pH after feeding and return to pre-feeding levels was noted.

Discussion

The purpose of this experiment was to determine the effects of initial, or abrupt, feeding of different grains to the C1 pH of alpacas and to show what varying levels of abrupt corn feeding would have on C1 pH. Alpaca producers are concerned about the potential bloating and other digestive perturbations that may result from the initial or abrupt intake of grains. Some feel that the incorporation of grains, no matter at what level or adjustment period, into the diet will result in detrimental digestive issues. The data obtained from this study will address some of these concerns.

Camelids have a unique digestive system that has a mucosal cellular structure associated with the first two stomachs called the glandular saccule. Eckerlin and Stevens (1973) indicated that the glandular saccule secrets significant amounts of bicarbonate increasing the buffering capacity within the stomachs. In addition to these saccules, Rubsamen and Engelhardt (1978) demonstrated that this glandular region is mainly for absorption of water and solutes where the absorption was 2 to 3 times greater than found in sheep or goats. For most ruminant animals, an abrupt change in diet (ie. abrupt increase in carbohydrate supply; grain) results in acute acidosis; a decrease in rumen pH due to the accumulation of lactic acid and other organic acids (Owens et al., 1998). Norlund and Garrett (1994) states that rumen pH of 5.0 to 5.5 is considered acidotic and pH 5.6 to 5.8 is marginal. One of our underlying goals for these experiments was to see if we could decrease C1 pH down to an acidotic level; somewhere around the 5.5 range. We did not think the grain inclusion in EXP 1 would result in this, but we did think that the G3C TRT from EXP 2 would decrease to this level.

The diurnal pH patterns we obtained from alpacas in this study were similar to those found by AlZahal et al., (2007). They showed in cattle fed alfalfa hay a decrease in pH following feeding and return to pre-feeding levels. Aguerre et al., (2009) in sheep fed pasture grass and sorghum grain, and Okamoto (1976) in sheep fed baled or cubed alfalfa hay also showed similar patterns. Based on these studies, typical forage fiber digestion and production of organic acids results in a slight decrease in diurnal pH patterns followed by a return; never decreasing below pH 6.0.

The amounts of O, C and COB fed in EXP 1 were about 35% of total DM intake and resulted in a pH ranging from 6.56 to 6.89. The inclusion of corn in EXP 2 was 0, 37, 55 and 74% of DM intake and ranged from 7.27 to 7.08. The difference in overall mean pH and diurnal pattern between the two experiments was not anticipated and may be due to the GH composition differences. The GH for EXP 1 does appear to be of higher quality, higher in crude protein and slightly lower in ADF and lignin. We did not determine digestibility of the forages and this may have given some indication if quality was a factor. The differences between the forage/grain patterns may be attributed not only to the forage substrate availability, but also the buffering capacity of the forage (Allen, 1997; Kohn and Dunlap, 1998). The significant decrease in pH for COB is thought to be due to the higher fermentability of the COB and associated molasses.

Aguerre et al., (2009), in sheep fed pasture grass and sorghum grain, included grain supplementation at 0, 14, 32 and 50% DM intake and showed rumen pH levels ranging from 6.45 to 5.43. These sheep were acclimated to the grain supplementation for 21 days before the pH was recorded, so acute, or abrupt, grain exposure pH values vs chronic. The decrease in pH with the 37 and 50% inclusion of grain was concluded to affect cellulolytic activity and fiber degradability. A pH of 6.7 is near optimal for cellulolytic activity (Van Soest, 1994).

Brossard et al., (2003) fed sheep a 60% wheat:40% alfalfa hay diets and looked at the pH response. They found that a significant amount of time within a 24-hr period rumen pH was below 6.0. Their aim was to look at the effects of latent or chronic acidosis on pH and the buffering system. The pH levels documented in our studies did not reach below 6.0. Corn starch and the other grains fed in our study are slower degrading than wheat starch but, at a higher ratio 75:25 concentrate:forage, the pH still did not reach 6.0. Brossard et al., (2003) concluded that in their study the low rumen pH was due to the effects of high carbohydrate intake on the carbonic acid and VFA buffering capacity. A more rapid absorption of solutes, including VFA's (Rémond et al.,, 1995), and the increase in buffering capacity by the glandular saccule secretions (Smacchia et al., 1995) can account for alpaca pH levels never reached below 6.0.

Initial or abrupt feeding of grains to alpacas does elicit a pH response, but not to the extent of other ruminants. The buffering capacity and rapid absorption of VFA of C1 may be key factors along with other factors that need to be determined. Additional studies need to be conducted to look at initial and chronic effects of popular grain supplements. Additional efforts need to determine the effects of highly fermentable substrates on diurnal pH and digestion dynamics to better understand camelid nutrition.

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